

TURBO-JET PUMP AND WATER JET ENGINE

TECHNICAL FIELD IN REGARD TO THE INVENTION

Turbo-jet pump - water-jet engine is by its design an axial turbo pump, with an additional structure for a fluid propulsive action, which makes this unit, by its design, a water jet engine, designed primarily to drive water vessels. Therefore it is classified as a pump, that is - a special axial pump, and also as an engine, that is – a special water jet engine.

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TECHNICAL PROBLEM

How to resolve the problem of designing a device which will drive vessels at high speeds, on the water surface and under water, that is ships and submarines, which will beat the resistance to movement at such speeds by a reactive action of a water jet, which will be of a small size, which will have a continual variation of delivery, i.e. number of rotor revolutions, and at the same time maintain a constant torque value, which will not be influenced by cavitations at any jet velocity, which will have double action of the jet and high efficiency.

All these, and some other, requirements are met by a turbo-jet pump - water-jet engine.

BACKGROUND ART

At the moment, a propeller, airscrew, mainly drives vessels on the water surface and under it, that is ships and submarines, with fixed or adjustable blades. There are some other, not so frequently employed, solutions, like Voith-Schneide airscrew. Propulsions are used partly with very small vessels for special applications (torpedoes).

The propeller, airscrew, has proved to be the best solution for driving vessels so far. However, the problems of its applications are only partly resolved. There is still the main problem – cavitations, and its applications are restricted only to certain speeds of vessels (cca 25 m/s, exceptionally up to 60 m/s - with a large number of propellers at smaller hydrofoil boats (skimmers), employing special materials resistant to cavitations influence.

Because of a relatively small number of the propeller revolutions in the water, there are some other problems connected with it's driving. For example, if a turbine (steam or gas) is employed, it is necessary to use a large speed reducer to reduce the number of revolutions; and if we employ diesel engines with a small number of revolutions, we encounter the problem of their overall dimensions and weight. We should also take into account a relatively low efficiency of the propeller (air-screw). The fundamental issue here is that the vessel speed depends on the number of the propeller revolutions, as it is practically a screw in the water.

Therefore, the advantage of the water jet engine is the fact that it has a constant thrust and it accelerates the vessel till the thrust and the resistance to movement achieve the same values, since when the vessel moves at a uniform (constant) speed.

DISCLOSURE OF INVENTION ESSENCE

Turbo-jet pump - water-jet engine, is by the design an axial, turbo pump, which is equipped with additional nozzles at the output to enlarge the speed of water jet discharge. Therefore, this structure is by its function a water jet engine, since it is employed to drive vessels. With the turbo jet engine (employed to drive flying objects) chemical energy is converted into thermal (kinetic) energy, whereas with the water jet engine electric energy is converted into mechanical (kinetic), and it is also possible to convert mechanical energy into mechanical (kinetic).

Turbo-jet pump - water-jet engine is employed primarily to drive vessels on the water surface and under it, that is ships and submarines, which are required to move at high speeds, over 50 m/s (over 185 km/h or over 100 knots) to 300 m/s (around 1100 km/h or around 600 knots).

The basic structure of the turbo-jet pump - water-jet engine driving the axial pump is equipped with a three phase asynchronous motor, using a high voltage current, of 1 kV, 6.3 kV or 10 kV, and higher operating frequencies, over 50 Hz (most often up to 300 Hz). This generates many advantages: small overall dimensions of the electric motor, and thus of the whole water jet engine, with direct actuation of the electric generator by turbines (steam or gas), without using a speed reducer, and low values of the employed currents (lower thermal losses).

Both sides of the electric motor shaft are equipped with the turbo pump rotors. The input rotor after-circuit and the output rotor pre-circuit are at the same time holders of the electric motor to the pump housing. Before the pump input rotor is a fixed pre/circuit, and after the output rotor is an after-circuit. Onto them are fixed rounded water distributors (most often shaped as the top of a cylindrical ellipsoid). Water is prevented from entering the electric motor by compressible pressure seals. As the water circulates between the input and output rotors, it simultaneously cools down the outer surface of the electric motor stator.

After the pump output rotor, that is after its after-circuit, the housing smoothly transforms into Venture's tube, in which the water jet accelerates. The water speed is at the critical pressure limit when the cavitations arise. The inner part of the jet engine housing is basically a tube, which is equipped with a suction pipe at the input, and it transforms into Venture's tube, as the nozzle, at the output. The outer side of the engine housing is formed so that it has a low resistance to movement, if installed on the outer surface of the vessel. If installed inside the vessel this requirement is not necessary.

The rotor of the turbo-jet pump - water-jet engine consists of a hub, a large number of blades and a ring connecting the blade tops. The rotor blades and guide circuit (stator circuits) blades, that are those of the pre-circuit and the post-circuit, can be standard ones, curved profiles, and also special designs. When the turbo-jet pump - water-jet engine is used for the jet double action, as the variant solution I, the rotor and the stator have to be equipped with the axis-symmetrical blades having an elliptic cross section, since the functions are altered then – the pre-circuit becomes the post-circuit, the front surface of the blade becomes the rear surface, and the jet becomes the suction pipe. This slightly reduces the efficiency rate, but the achieved function of the water engine is more important. Such turbo-jet pump - water-jet engine, as the variant solution I, is used as the submarine drive for fast diving or surfacing, or fast lateral movement in motion or when stationary. The blades can also be inclined or curved in the rotation direction, or in the opposite direction, by a small angle to the radial direction. As a rule, the blades are used for actuation.

As a rule, the rotor hub diameter is equal to the electric motor (stator) external diameter. The blade tops have to be connected with a ring. This eliminates the harmful effect of the centrifugal force onto the water mass rotating between the blades and the stationary housing. This also eliminates the effect of the blade tops, and the effect of the clearance between the blades and the housing. This ring practically rotates inside the housing, since its internal diameter is equal to the housing internal diameter.

As a rule, the suction pipe has rounded edges. When the turbo-jet pump - water-jet engine is installed onto the outer surface of a vessel, the suction pipe is to be equipped with a hard net, and the best one is convex, or in the shape of the top of a cylindrical ellipsoid. The water jet engine with the double-acting jet is equipped with these nets on both sides, so that it would be protected against damaging which might be caused by penetration of a hard object.

The water discharge and velocity through the turbo-jet pump - water-jet engine, when driven by an electric motor, are regulated by continual variation of the operating frequency. In this case the torque maintains the constant value over a wide range of the number of revolutions of the motor.

Variant II: the energy necessary to operate the turbo-jet pump - water-jet engine is supplied by a shaft from inside the vessel, similar to supplying the energy to the propeller, which is axially connected to the

armature shaft. In this case, the suction pipe has to be adjusted, since the water engine is connected through it to the vessel's side by connecting rods. This variant is designed for the single-acting jet.

Variant III: the energy necessary to operate the water engine is supplied from the inside of the vessel by a shaft which radially fits between the front and the rear rotors of the pump, and it supplies the energy to the pump shaft via conical gears or differential gear. In this case it is possible to obtain double acting of the water jet. These variants, and those similar to them, are suitable for smaller vessels and lower speeds.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 – longitudinal cross section of the electrically driven turbo-jet pump - water-jet engine for single acting of the water jet

Figure 2 -longitudinal cross section of the electrically driven turbo-jet pump - water-jet engines for double acting of the water jet, variant solution II

Figure 3 – variant II, the pump driven through an axially connected shaft

Figure 4 – variant III, the pump driven through a radially driven shaft

Figure 5 – scheme of the front view of the pump rotor segment with radially placed blades

Figure 6 – a) flat axis-symmetrical blade with an elliptic cross section, b) unfolded grid of the rotor, pre-circuit, post-circuit with flat axis-symmetrical blades for CW and CCW revolutions of the rotor and double acting of the water jet.

DETAILED DISCLOSURE OF THE INVENTION

The fundamental design of the turbo-jet pump - water-jet engine is shown in Figure 1. The housing is of cylindrical shape, and in its rear part, after the pump, through larger rounding, it transforms with large radii into Venture's tube 16. Before the pump section is the suction pipe 2. It is of small size and has rounded edges, if installed onto the vessel's side or employed for other applications, e.g. in the pools for testing of vessel cross-section or model blades (which is not the case at present). When it is installed within the vessel, the suction pipe extends to the opposite side, in the direction of the vessel moving, and through that pipe the water is supplied to the pump-engine. This provides the water supply at the rate similar to the speed of the vessel.

The energy necessary to operate the turbo jet pump is supplied by a three phase asynchronous motor consisting of the shaft 8, short-circuited rotor 9, stator with windings 10, and bearings within the covers 11. The electric motor operates at three phase electric energy, of a high operating voltage – 1 kV, 6.3 kV or 10 kV, which depends on the required overall dimensions and thrust. When high voltages are used, the power is lower, so the losses at generating heat are lower. The operating frequency is lower, 100 Hz or more, in order

to obtain the number of revolutions of 3000 – 9000 1/min (using multiple motors). As a rule, with smaller turbo-jet pump - water-jet engine the maximum number of revolutions is lower, and vice versa. Practically, a high voltage and a large number of revolutions obtain smaller overall dimensions of the motor for the same power. The advantage of using higher frequencies is that the turbine (steam or gas) or a diesel engine of a high number of revolutions actuates electric generator direct, without a speed reducer, and generates a high voltage current, so that the reduction of the number of revolutions is not required, either. When operating circuits with a large number of revolutions are used, it is possible to install a larger number of smaller blades, and at the same time obtain a very high discharge of the water through the pump.

The number of revolutions, and thus the flow and discharge head of the pump, are achieved by varying the operating frequency. The frequency variation is achieved direct by varying the number of electric generator revolutions, or by special frequency converters (microinverters). At the same time the torque maintains about the same value within a wide range of variations of the number of revolutions. The former method of frequency variations is better, but it is not feasible when several turbo-jet pump - water-jet engine perform simultaneously several functions on the same vessel. This is the case of submarines, when e.g. it is moving forward, and it is to move laterally along with diving or surfacing. With vessels on the water surface, ships, this is necessary with vessels for special purposes.

Compressible pressure seals 6 are employed to prevent penetration of water into the electric motor. This water could damage bearings and the stator windings. The bearings can be lubricated by special lubricating greases, or by oil using a pump and an oil duct within the vessel. Bearings 11 are radially axial for high number of revolutions.

At the ends of the electric motor shaft are fixed the pump rotors: input 5, and output 13. Before the input circuit is the pre-circuit 4, and after the output rotor is the post-circuit 14. Both of them are fixed to the housing via the blades. Both of them simultaneously hold water deflectors 3 and 15. These deflectors are, as a rule, tops of a cylindrical ellipsoid. After the pump input rotor is the post-circuit 7, and in front of the output rotor is the pre-circuit 12. These stator circuits are fixed to the housing via the blades, and at the same time they hold the electric motor, that is the conveyor gears housing for shaft (8) driving, through which the pump circuit rotors (24) are driven.

When the turbo-jet pump - water-jet engine is installed onto the side of a vessel, it is to have a hydro-dynamically shaped cover (the best shape is cylindrical ellipsoid), the suction pipe is to be protected by a sieve 18, to prevent penetration of mechanical impurities that could damage the circuits of the turbo-jet pump - water-jet engine.

The operating circuit of the axial pump consists of the rotor hub 24, blades 25 and the ring connecting the blade tops. As a rule, the hub diameter is equal to that of electric motor stator, but it can also be larger. The

hub width depends on the blade length and their angle of inclination β to the rotation axis (the angle of sieve inclination).

The rotor and stator blades can be of different designs. The standard turbo-jet pump - water-jet engine with the single acting jet, employs "standard", curved blades with the normal hydrodynamic cross-section. As a rule, they are intended for the active function and are radially placed to the rotation axis, but they can also be beveled or bent to the radial direction. The pre-circuit inputs and the post-circuit outputs are in the direction of the revolution axis. A detailed calculation of the axial turbo pump depends on the required thrust, and the whole water jet engine depends on it. The calculation is not given herein, as it is well known in mechanics of fluids and design of turbo machines. When the blades are manufacture, we should pay attention to the cross-section accuracy and make sure that they have smooth surfaces, since water can flow through the sieve at the speed of several hundreds m/s. The same applies to the housing internal surface of the turbo-jet pump - water-jet engine.

The ring 26 on the blade tops of the pump rotor is compulsory. It has many functions. It eliminates the blade vibrations, which can appear if the tops are free, it eliminates the cross-section effect of the blade tops, eliminates the effect of the clearance between the blades and the housing, eliminates high friction which could appear between the fluid in the area within the blades and the housing due to the effect of high centrifugal forces, and it takes over a part of the centrifugal force on the blades. Installation of the ring allows the use of thinner blades, which reduces the resistance to the water discharge. As a rule, the internal diameter of this ring is equal to the internal diameter of the pump housing, but it can also be smaller. This practically means that it rotates within the circular groove on the internal wall of the pump housing.

The static thrust achieved by the turbo-jet pump - water-jet engine equals to:

$$F_p = m_v * v_v = \rho * Q * v_v \quad [N],$$

Where:

ρ [kg/m³] - water density at a certain temperature and depth

Q [m³/s] - volumetric water flow

v_v [m/s] - discharge ratio of water through the nozzle

In order to increase the static thrust of the jet, the water after the pump flows through the Venture's tube, which increases the discharge ratio. The fundamental issue with the basic design, and with any variant, is to achieve the mass flow as high as possible along with the discharge ratio as high as possible. At the same time we must make sure that at any water flow, marked I – XI, discharge ratio be close to the critical pressure, when the cavitations appears, and the achieved pressure (discharge head of the pump) in the pump should be slightly higher than the one required to beat the incidental and local resistance. At this point the optimal

solution is achieved – the highest thrust along with the highest efficiency of the turbo-jet pump - water-jet engine. That is why it is used for achieving high speeds of vessels on the water surface and under water, ships and submarines, over 50 m/s (over 185 km/h or 100 knots), up to 300 m/s (cca 1100 km/h or cca 600 knots).

Variant solution I is the design of the turbo-jet pump - water-jet engine for double acting of the thrust, that is the jet, by alternating the direction of the pump rotor revolution. In that case both ends of the turbo-jet pump - water-jet engine are equipped with the Venture's tube 16. Alternating the direction of the rotor revolution causes the alternation of the functions of the pump parts – the input rotor becomes the output one, and vice versa, the post-circuit becomes the pre-circuit, and vice versa, the nozzle becomes the suction pipe. In this case the rotor and the stator blades (pre-circuit and the post-circuit) have to be flat and axis-symmetrical 25, since by alternation of the revolution direction the front surface of a blade becomes the rear surface, and vice versa. In that case the best cross-section of the blade is an ellipse 25, with the semi-axis ratio $a:b$ from 8:1 to 20:1. This means that the blade thickness δ is 8 to 20 times less than length l . Besides, the highest flow is obtained when the blades are inclined at the angle $\beta = 45^\circ$ to the revolution axis (the sieve inclination). Figure 6 shows the velocity ratios (circumferential velocity u , relative velocity w and absolute velocity c), and the force ratios (circumferential, tangential F_u and axial F_z). This variant solution I of the turbo-jet pump - water-jet engine has a slightly lower efficiency than the basic design, but the effect of double acting is more important, which is very important with submarines, so that they can dive or surface very fast.

The variant solution II of the drive of the turbo-jet pump - water-jet engine is through a connecting shaft from the vessel. Instead of an electric motor, the shaft 8 is connected to the driving shaft 19 via a coupling 20, axially placed in the suction direction, and driven by a motor within the vessel. In this case the turbo-jet pump is connected to the rear (stern) section of the vessel by levers. This variant is applicable to a single-acting jet. It is employed with smaller vessels and for lower powers. In this case the energy of the initial driving engine need not be converted into electric energy, and this into mechanical (kinetic) energy.

Variant solution III also involves driving of the turbo-jet pump via a shaft from the internal section of the vessel 22, but radially placed to the pump axis, in the middle between the operating circuits. Instead of the electric motor, as with the basic design of the turbo-jet pump - water-jet engine, here is a speed reducer or multiplicator with a disc gear 23 or a differential conveyer. This variant solution can be employed for the double-acting jet, and also for lower powers, that is speeds and smaller vessels. Other variant solutions do not have an important role in practice.

INVENTION INDUSTRIAL OR OTHER APPLICATIONS

The description clearly indicates that the turbo-jet pump - water-jet engine is to be employed to drive vessels on the water surface and underwater, ships and submarines, and to set them at high speeds. It can also

be used for testing of the cross-sections of model ships and submarines, and blades in special tunnels in the hydrodynamic tunnel and channel (a separate patent), at the principle of testing the cross-sections in air-dynamic tunnels, which is not case at present. If need be, it can also be employed for other purposes.